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Original Article

A Biometric System for Iris Recognition Based on Fourier Descriptors and Principle Component Analysis

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Abstract *Iris pattern is one of the most important biological traits of humans. In last years, the iris pattern is used for human verification because of uniqueness of its texture. In this paper, biometric system based iris recognition is designed and implemented using two comparative approaches. The first approach is the Fourier descriptors, in this method the iris features have been extracted in frequency domain, where the low spectrums define the general description of iris pattern, while the high spectrums describes the fine detail. The second approach, the principle component analysis uses statistic technique to select the most important feature values by reducing its dimensionality. The biometric system is tested by applying one-to-one pattern matching procedure for 50 persons. The distance measurement method is applied for Manhattan, Euclidean, and Cosine classifiers for purpose of comparison. In all three classification methods, Fourier descriptors were always advanced principle component analysis in matching results. It satisfied 96%, 94%, and 86% correct matching against 94%, 92%, and 80% for principle component analysis using Manhattan, Euclidean, and Cosine classifiers respectively.*

Index Terms— **Iris recognition, Fourier descriptors, Principle component analysis, Manhattan distance, Euclidean distance, Cosine distance.**

I. Introduction

In recent years the use of biometric systems has increased with the encouragement of both governmental and private agencies to supersede or improve the traditional security systems. The iris recognition is usually one of the most reliable biometric measures. The conventional techniques like user name, keys, ID cards, passwords, hardware code based systems are not authoritative and safe in many of the security areas. So, there is an increasing need for authoritative authentication process in the modern society. In the last few years, the biometric identification proved to be more reliable for the human verification and identification. Biometrics method can be described as automate technique to recognize person automatically relied on his or her behavioral and/or physiological features by using computers. The iris recognition system is a comparatively new biometric system compared to other biometric systems. This system is considered as one of the most accurate systems to recognize the persons and produces the better results in comparison with other biometric system such as face, voice, retina, fingerprint, etc. [1]. This paper presents a novel procedure of iris recognition using Fourier descriptors (FD) and Principle Component Analysis (PCA). The main idea of Fourier descriptors is to describe the contour by a set of numbers which represents the frequency content for full form, so it encodes any two dimensional object by transforming its boundary into a complex numbers in frequency domain. This transformation is based to extract the iris features and create the templates. Relying on the frequency analysis will generate a small set of numbers called the Fourier coefficients, which describes the shape and not the noise like that influences on the spatial position for boundary pixels. PCA is a technique used for decreasing the dimension of the problem state. It provides effective measure to decrease a complex dataset to lesser the dimension with minimal additional exertion.

The rest of the paper is organized as follows: Section II related work; Section III describes the proposed iris recognition system respectively. Section IV tabulates the recognition results of three distance measures methods; it shows the accuracy rate for each method that was applied on 50 iris images. Eventually, section V discusses and concludes the highest accuracy result and its related three distance measures.

II. RELATED WORK

The idea of utilizing the iris in human identification was suggested in 1936 by ophthalmologist Frank Burch. In 1987, Aran Safir and Leonard Flom, the two American ophthalmologists adopted Burch's idea of identifying people based on individual iris features, but their clinical experience were unable to develop such a process. In 1993, J. Daugman [2] used phase code by applying "Gabor filters" for iris recognition. The system is registered excellent performance on different databases of large numbers of images. In matching phase he used Hamming distance between two codes (bit to bit). Daugman system achieved high accuracy and high speed performance, he satisfied accuracy rate of 99.90%. In 1997, Wildes [3] proposed a technique to describe an iris recognition system by using a diffused source and polarization with low light level camera for image capturing at Sarnoff laboratory. Wildes' system used a gradient based on binary edge-map followed by Hough transform (HT), and used Laplacian of Gaussian filter to create a feature template. Wilde's system used 520 iris images and this system reports high performance with 98.24% accuracy rate. Son et al. in 2004 [4] utilized a linear discriminant analysis (LDA), a Discrete Wavelet Transform (DWT), Principal Component Analysis (PCA), and Direct Linear Discriminate Analysis (DLDA) to extract the features. These features experimented on combinations for iris recognition. In 2007, R. Al-Zubi and D. Al-Nadi [5] utilized a circular Hough transform and polynomial fitting technique in segmentation process. Sobel edge detector is used to find the pupil's location and area. Also, Log-Gabor filter is applied to extract and encode the feature vectors. This algorithm acquired best performance that obtained 99% accuracy rate. In 2008, R. Abiyev and K. Altunkaya [6] suggested a fast algorithm for localization of the inner and outer boundaries of the iris region to extract an iris from an eye image by applying a Canny Edge Detection and a Circular Hough Transform, a neural network (NN) was used for classification of iris image patterns. In 2013 G. Kaur [7] suggested two different methods for iris recognition. Support Vector Machine (SVM) is the first method, and the second one is a phase based procedure. SVM showed Average FRR=19.8%, and FAR = 0%. A phase based procedure showed FRR = 0.01%, FAR = 0.09% and overall accuracy rate = 99.9%. In 2015, Homayon [8] suggested a new neural network method for the iris recognition. The proposed method is achieved using image processing techniques. LAMSTAR neural network (LArge Memory STorage And Retrieval) is applied for classification which utilizes CASIA-v4.0-interval database. Tests are applied on 16 different images for both right and left eyes of 8 persons; the accuracy rate is 99.57% for this algorithm. In 2016, A. Kumar et al. [9] suggested a method for the iris feature extraction and recognition relied on 2D discrete cosine transform. It applied 2D DCT to extract the most discriminating features of an iris. The extracted features have been tested on two publicly available; IIITD and CASIA v.4.0 database, in matching phase the iris templates using Hamming distance. The proposed algorithm is obtained accuracy rate of 98.4% and 99.4% on IITD and CASIA V4 database respectively. In 2017, Muthana H. Hamd and Samah K. Ahmed [10] used Fourier descriptors for feature extraction and four classifiers for verification process; Back-Propagation (BP), Radial Basic Function (RBF), probabilistic and Euclidean Distance (ED). They obtained 96.67% accuracy rate for BP and ED, while RBF and probabilistic attained 83.33% and 86.67% respectively. A. Gaikwad and Mouad M. H. Ali [11] used Wavelet decomposition and hamming distance for iris recognition and they find different accuracy rate with different data set size for training and testing with highest accuracy of them reach to 89.03%.

III. PROPOSED IRIS RECOGNITION SYSTEM

The system components are built and programmed using MATLAB (R2016b) commands. The proposed method consists of five stages; image acquisition, iris segmentation, iris normalization, feature extraction, and pattern matching. Figure 1 shows the procedure for proposed iris recognition system using FD and PCA as feature extraction; it explains the procedures of FD and PCA method step by step. The steps of the proposed algorithm are as follows:

1. Image Acquisition

In this system the eye images are taken from the Chinese Academy of Sciences Institute of Automation (CASIA) dataset for iris recognition system. The image is 320×280 pixels taken from a distance of 4-7 centimeters.

2. Iris Segmentation

Iris segmentation operation includes two steps (pupil and iris localization). These steps should be achieved with high fineness because they significantly affect the decision of the authentication process. Below the two steps described:

A. Pupil localization

The pupil region can be detected and localized by the following steps:

Step1: apply filter median on the eye image to reduce the effects of eyelid and eyelashes.

Step2: convert the grayscale image to binary image by suitable threshold (τ), as in (1).

$$I(x, y) = \begin{cases} 1 & \text{if } f(x, y) = \tau \\ 0 & \text{if } f(x, y) <> \tau \end{cases} \quad (1)$$

Step3: apply the opening and closing operations on the binary eye image I(x, y) for noise removal.

Step4: Connected component labelling algorithm is used to make the edge of object is connected.

Step5: Find the pupil center P_x and P_y which by calculating the summation of the horizontal and vertical vectors as in (2) and (3), then find the maximum row and column vector respectively as in (4) and (5).

$$hor(x) = \sum_{1}^{x} \text{all rows} \quad (2)$$

$$ver(y) = \sum_{1}^{y} \text{all cols} \quad (3)$$

$$p_x = \max(hor) \quad (4)$$

$$p_y = \max(ver) \quad (5)$$

Where *x* represents (no. of rows) and *y* represents (no. of columns).

Step6: Find the radius of the pupil (r_P), as in (6).

$$r_p = (\max(hor) - \min(hor))/2 \quad (6)$$

B. Iris Localization

Canny edge detector and circular Hough transform are both used for iris localization. Canny filters are very important as they applied to locate the boundaries of iris contour. Next, a circular Hough transform is applied to obtain a complete circle shape and locate the center and radius of the iris.

3. Iris Normalization

Normalization is an essential step for better verification result. It minimizes the distortion resultant from pupil motion. The process begins by converting the iris region that is clear in a circular shape to a rectangular one. Daugman's rubber sheet model is applied to convert the Cartesian coordinates to polar form. The idea of polar form is to give 20 pixels along r and 240 pixels along θ to produce unwrapped strip size of 20 × 240 which will stay invariant for image skewing or extension. Equations, (7) and (8) are the mapping functions from Cartesian coordinates (x, y) to polar form (r, θ) are [1]:

$$X(r,\theta) = (1-r) * X_p(\theta) + r * X_i(\theta) \quad (7)$$

$$Y(r,\theta) = (1-r) * Y_p(\theta) + r * Y_i(\theta) \quad (8)$$

And,

$$X_p(\theta) = X_{po}(\theta) + r_p * \cos(\theta) \quad (9)$$

$$Y_p(\theta) = Y_{po}(\theta) + r_p * \sin(\theta) \quad (10)$$

$$X_i(\theta) = X_{io}(\theta) + r_i * \cos(\theta) \quad (11)$$

$$Y_i(\theta) = Y_{io}(\theta) + r_i * \sin(\theta) \quad (12)$$

Where,

(X_p, Y_p): is the center of pupil,

(X_i, Y_i): is the center of iris,

(r_p, r_i): are the radius of pupil and iris respectively.

4. Feature Extraction

In feature extraction stage, two different approaches are applied to prepare the database and the input patterns for the next matching stage.

A. Fourier Descriptors

The extracted iris patterns are not ready yet for comparison. There are many approaches for template generation such as: Gabor wavelet; zero-crossing wavelet; local variance; spatial filters; and 1D local texture pattern. FDs are considered here to create the feature vectors and templates by computing the shape transformed coefficients form in frequency domain. The low frequency descriptors represent the information about the general features of the object while the high frequency descriptors represent the information about accurate details of the object. The number of created coefficients from the transformation is usually large, so just sufficient coefficients can be selected to describe the object features [12]. The FD procedure is:

Step1: Count boundary points.

$$z(t) = x(t) + i * y(t) \qquad (13)$$

Step2: choose the sampling number, N.

Step3: Calculate the centroid distance.

$$r(t) = \sqrt{[x(t) - x_c]^2 + [y(t) - y_c]^2} \qquad (14)$$

$$x_c = \frac{1}{N}\sum_{t=0}^{N-1} x(t) \ , \quad y_c = \frac{1}{N}\sum_{t=0}^{N-1} y(t) \qquad (15)$$

The centroid distance represents the location of the shape from the boundary coordinates, that makes the representation is invariant to translation [12].

Step4: Compute Fourier transforms values.

$$FD_n = \frac{1}{N}\sum_{t=0}^{N-1} r(t) * \exp\left(\frac{-2j\pi nt}{N}\right) \qquad (16)$$

Where FD_n, n = 0, 1, …, N-1,

Step5: Normalize the FD coefficients by dividing them on the DC value.

$$F = \frac{|FD_1|}{|FD_0|}, \frac{|FD_2|}{|FD_0|}, \ldots, \frac{|FD_{N/2}|}{|FD_0|} \qquad (17)$$

The extracted features are very large, the FDs coefficients are 512. The size of the coefficients must be reduced to 150 from 512 coefficients in this work to make the suggested system simple and fast.

B. Principle Component Analysis

The main idea of using PCA is to find the feature vectors. This technique is known as the Hotelling transform. PCA uses the factorization to transform data according to its statistical properties. The data transformation is especially useful for the classification and compression. A mathematical procedure that converts a number of possibly correlated variables into a smaller number of uncorrelated variables called principal components. Also data can be decreased or compressed by eliminating the less important elements. The data elements can be seen as features in mathematical sense; they define the axes in the coordinate system [13]. The PCA procedure is:

Step1: Calculate the covariance matrix ∑X (which *X* represent features vector). This matrix provides the information about linear independence between features.

$$\sum X = \begin{bmatrix} \sigma_{x,1,1} & \sigma_{x,1,2} & \cdots & \sigma_{x,1,n} \\ \sigma_{x,2,1} & \sigma_{x,2,2} & \cdots & \sigma_{x,2,n} \\ \vdots & \vdots & \vdots & \vdots \\ \sigma_{x,n,1} & \sigma_{x,n,2} & \cdots & \sigma_{x,n,n} \end{bmatrix} \qquad (18)$$

$$\sigma_{x,i,j} = \left[\left(c_{x,i} - \mu_{x,i}\right) * \left(c_{x,j} - \mu_{x,j}\right)\right] \qquad (19)$$

Where $c_{x,i,j}$ represent the feature vectors and $\mu_{x,i,j}$ represent the mean of the summation the vectors.

Step2: Find the eigen-values using the characteristic equation, as in (20) which these values represent the diagonal covariance matrix ∑Y .

$$\det(\lambda_i I - X) = 0 \qquad (20)$$

$$\sum Y = \begin{bmatrix} \lambda_1 & 0 & \cdots & 0 \\ 0 & \lambda_2 & \cdots & 0 \\ \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & \cdots & \lambda_n \end{bmatrix} \qquad (21)$$

Step3: find the eigenvectors through solving (w_i) in $(\lambda_i I - X)w_i = 0$ for all eigen-values. Eigenvectors must be linearly independent and normalized.

Step4: find the transformation W is obtained by considering the eigenvectors as their columns.

$$W = \begin{bmatrix} w_{1,1} & w_{1,2} & \cdots & w_{i,n} \\ w_{2,1} & w_{2,2} & \cdots & w_{2,n} \\ \vdots & \vdots & \cdots & \vdots \\ w_{n,1} & w_{n,2} & \cdots & w_{n,n} \end{bmatrix} \quad (22)$$

Step5: find the transform features by calculating

$$C_Y = C_X * W' \quad \text{or} \quad C_Y = W * C_X' \quad (23)$$

For classification, it must select features with the large values of (λi). When (λi) measures the variance, and the features that contain the large range of values will be had large variance [13].

Step6: normalize the transform features (C_Y) vector by dividing them on DC value, as in (24).

$$C = \frac{|C_1|}{|C_0|}, \frac{|C_2|}{|C_0|}, \ldots, \frac{|C_{N/2}|}{|C_0|} \quad (24)$$

Where N represents the numbers of the transform features.

5. Pattern Matching

The last stage contains two phases: training and testing. In training phase, 300 iris images were chosen for 50 persons, each person has 6 images for right eye.

In testing phase, 50 right iris images belong to 50 persons were considered. All these images are taken from CASIA-V4 iris images database. The three distance measurement methods: Manhattan, Euclidean, and Cosine are all programmed for running the classification process. The distance between the testing template vector and the stored training vectors are computed using the following measurement distance methods [14]. The value of threshold (1 to 8) is generated from distance matrix. The distance is checked if it less than threshold value that means it is from same class otherwise it belongs to different class.

- **Manhattan distance**

$$d(X,Y) = \sum_{i=1}^{n} |X_i - Y_i| \quad (25)$$

- **Euclidean distance**

$$d(X,Y) = \sqrt{\sum_{i=1}^{n} (X_i - Y_i)^2} \quad (26)$$

- **Cosine distance**

$$d(X,Y) = 1 - \frac{\sum_{i=1}^{n} (X * Y)}{\sqrt{\sum_{i=1}^{n} Y^2 * \sum_{i=1}^{n} X^2}} \quad (27)$$

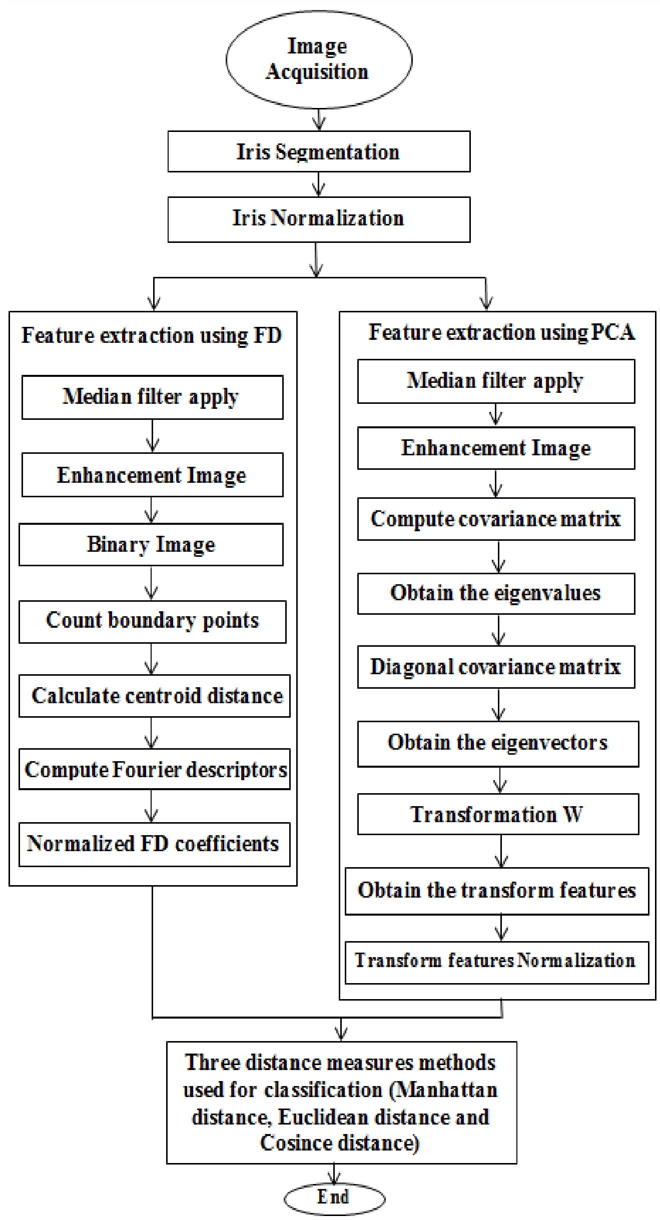

Fig. 1 Iris recognition system procedure using Fourier descriptors and principle component analysis

IV. EXPERIMENTAL RESULTS

The suggested system is tested on 350 images for 50 persons; each person has 6 images for training and one image for testing. Figure 2 shows the proposed algorithm results for iris segmentation steps. The figure explains the results of some processes like: image de-noising, morphological operations, connected component labeling algorithm, pupil and iris localization, circle iris region to rectangular form converting (iris normalization), and iris image enhancement. The proposed segmentation procedure is applied to segment pupil/iris using 756 and 1000 iris images for CASIA-v1 and CASIA-v4-interval respectively. The use of morphological operations and connected component labeling algorithm improves the accuracy rate of our segmentation procedure from 80% to 100%. Figure 3 and Figure 4 show the verification performance or accuracy rate versus different threshold values for FD and PCA method respectively. These figures show Manhattan distance advances Euclidean and cosine methods in both FD and PCA. Three important metrics are used for performance evaluation measurement, they are: False Accept Rate (FAR), False Reject Rate (FRR) and Accuracy rate (Acc) as described in (28), (29), and (30). Table I displays the test performances of FAR, FRR and Acc rate for iris recognition system using FD and PCA for three distance methods (Manhattan, Euclidean and Cosine distance). This table shows the total running time of iris recognition system for all three distance measurement methods.

$$FAR = \frac{\text{No. of accepted imposter}}{\text{Total no. of imposter assessed}} * 100\% \qquad (28)$$

$$FRR = \frac{\text{No. of rejection genuine}}{\text{Total no. of genuine assessed}} * 100\% \qquad (29)$$

$$\text{Acc (\%)} = (N_c / N_t) * 100 \qquad (30)$$

Where,

N_c : denotes to the number of correct iris samples.

N_t : is the total number of iris samples.

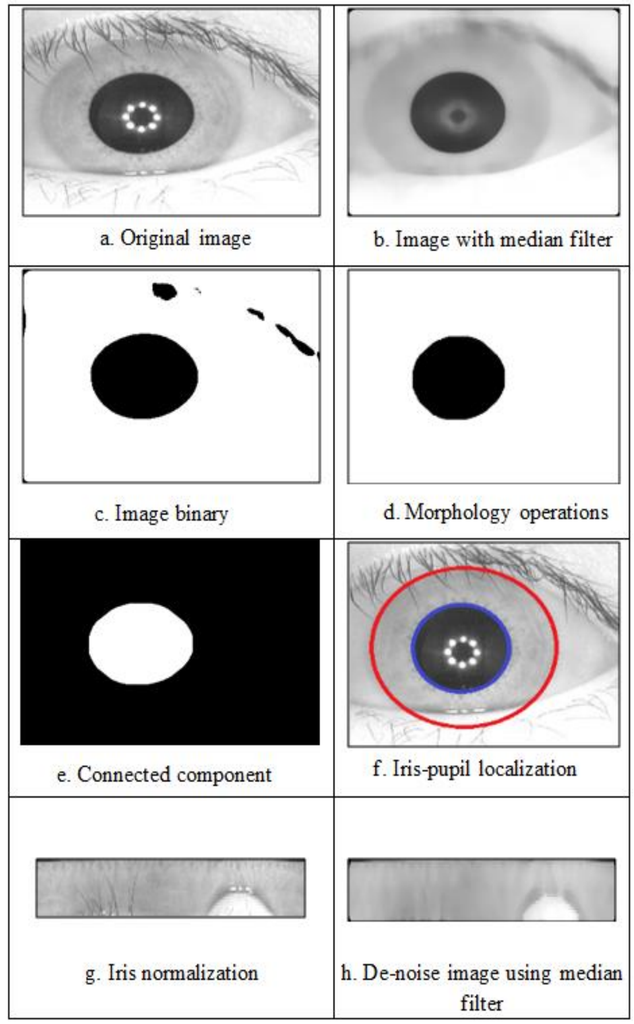

Fig. 2 The proposed algorithm result

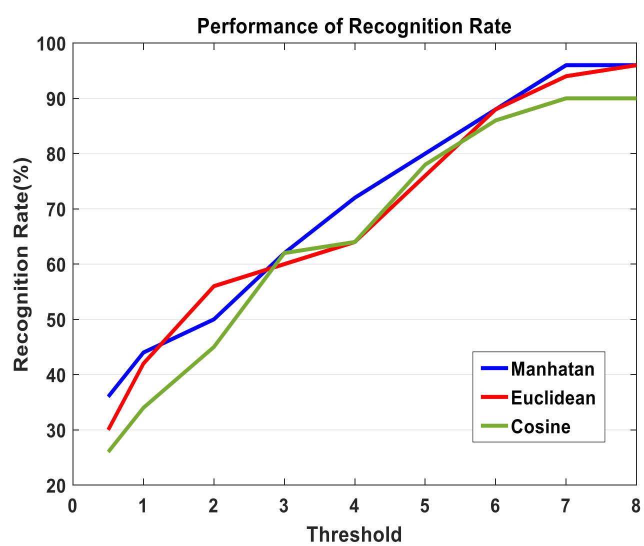

Fig. 3 Performance comparison between Manhattan, Euclidean and Cosine distance for Fourier descriptors

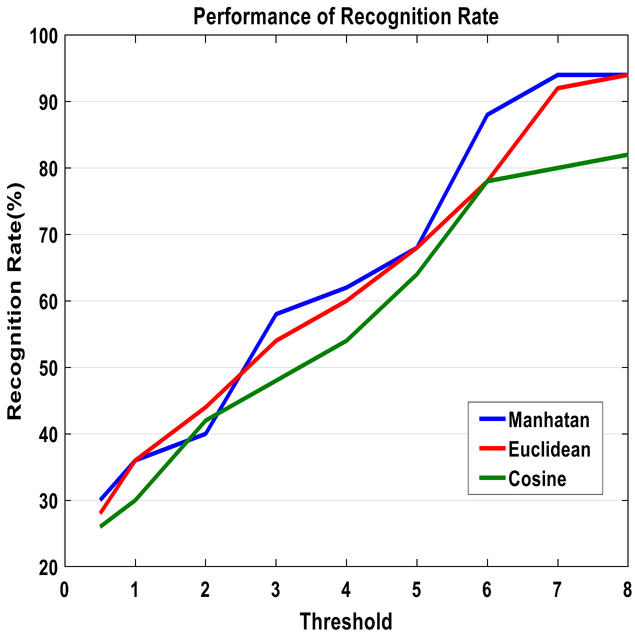

Fig. 4 Performance comparison between Manhattan, Euclidean and Cosine distance for principle component analysis.

TABLE I
PERFORMANCE COMPARISON BETWEEN FOURIER DESCRIPTORS AND PRINCIPLE COMPONENT ANALYSIS FOR 50 PERSONS

Methods	Distance measures	FAR %	FRR %	Acc %	Total Time (sec)
FD	Manhattan	0.009	0.081	96	134.203
	Euclidean	0.012	0.122	94	138.205
	Cosine	0.041	0.285	86	138.508
PCA	Manhattan	0.008	0.122	94	191.85
	Euclidean	0.015	0.163	92	195.4
	Cosine	0.019	0.408	80	196.7

From this table, Manhattan distance method achieved good results comparing to Euclidean and Cosine distance methods. It satisfied less FAR, less FRR, less running time, and high accuracy rate for both FD and PCA. The proposed system failed at some cases because some images are not clearly and contain effects of eyelid and eyelashes.

V. CONCLUSION

In this paper, a biometric system for iris recognition is implemented. The idea of system is relied on Fourier descriptors and principle component analysis as two comparative feature extraction methods. The new idea is the iris feature patterns that have been extracted in frequency domain using FD, where only sufficient coefficients of the transformed features were selected. In PCA method, collection of orthogonal basis vectors is created from a group of sample images. By selecting the most controlling vectors, it makes the dimension of the sample images decreased at the expense of little loss of information. The iris localization and segmentation acquired 100% accuracy rate. The performance of FD was most effective, it satisfied 96% accuracy rate with FAR=0.009, FRR= 0.0816 and 134.203 sec training time for Manhattan while Euclidean and Cosine produced 94% and 86% respectively. PCA gave 94% accuracy rate with FAR=0.008, FRR= 0.1224 and 191.85 sec training time for Manhattan, while Euclidean and Cosine produced 92% and 80% respectively. Based on the above, Manhattan achieves the best results with minimum time from Euclidean and Cosine in FD and PCA.

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